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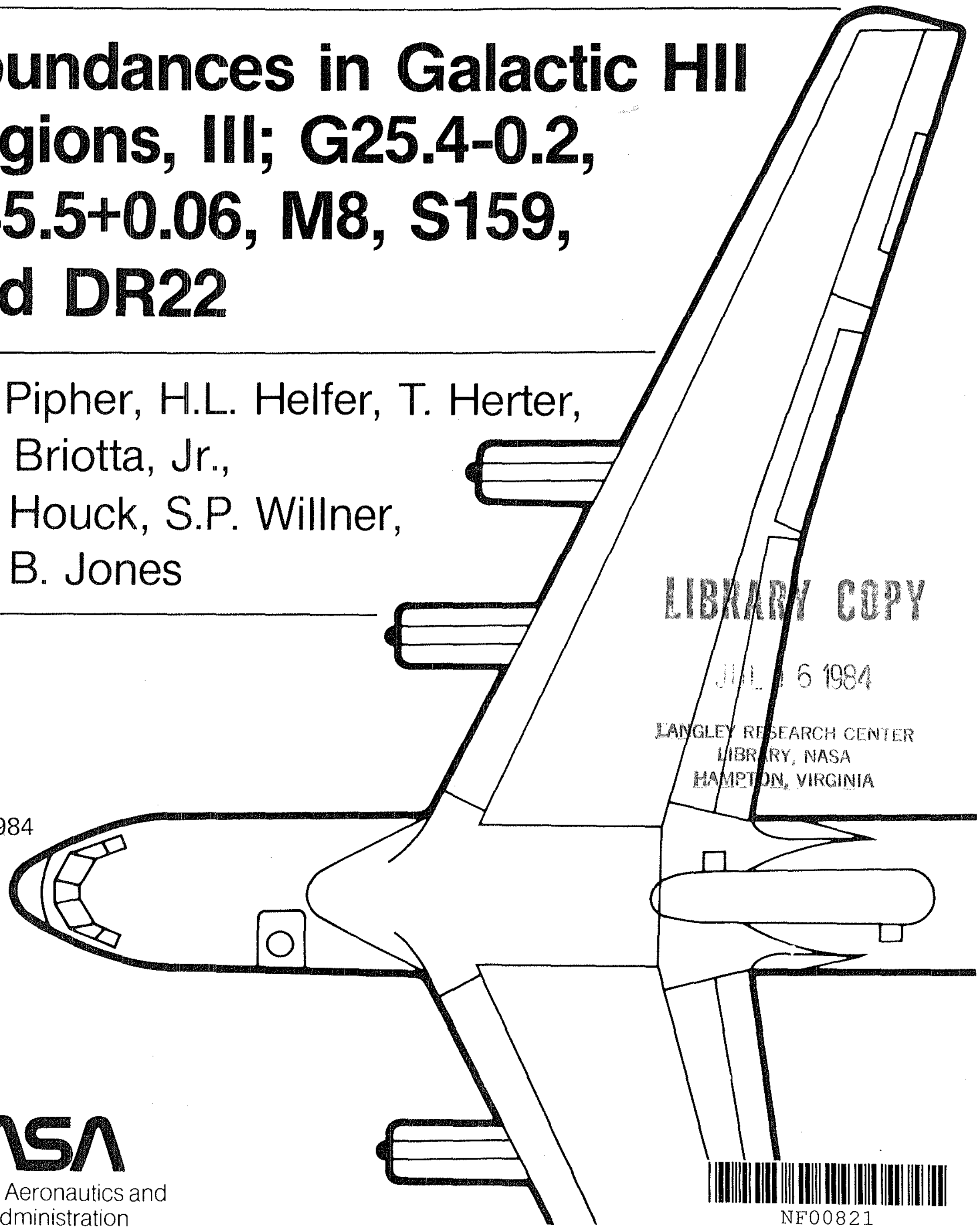

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ABUNDANCES IN GALACTIC HII REGIONS, III;

G25.4-0.2, G45.5+0.06, M8, S159 and DR22

by

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ABSTRACT

Measurements of the [ArII](6.99μm), [ArIII](8.99μm), [NeII](12.81μm), [SIII](18.71μm), and [SIV](10.51μm) lines are presented for five compact HII regions along with continuum spectroscopy. From these data and radio data we deduce lower limits to the elemental abundances of Ar, S, and Ne. G25.4-0.2 is only 5.5 kpc from the galactic center, and is considerably overabundant in all these elements. G45.5+0.06 is at 7 kpc from the galactic center, and appears to be approximately consistent with solar abundance. S159 in the Perseus Arm, at 12 kpc from the galactic center, has solar abundance, while M8 in the solar neighorhood may be somewhat overabundant in Ar and Ne. DR22, at 10 kpc from the galactic center in the Cygnus arm, is overabundant in Ar. A summary of results from our series of papers to date on abundances is given.

I. Introduction

This is the third paper in a series presenting observations of infrared fine structure line strengths in galactic HII regions for the purpose of assessing abundances in the Galaxy. Hereafter Paper I, II are used to refer to Herter *et al.* 1981, 1982a, respectively. As we have pointed out before, infrared observations allow one to probe large distances from the Sun or deep within a molecular cloud, although substantial extinction corrections are required in these cases. The weak temperature dependence of the line strengths and the potential for obtaining data on two important ionization states of the argon and sulphur atoms allow direct abundance analysis using the infrared lines.

In this paper we report ground-based and airborne spectroscopic fine structure line observations from 2-30μm for the compact HII region complexes of G25.4-0.2, G45.5+0.06, M8, S159, and DR22. The regions G25.4-0.2 and G45.5+0.06 are near the regions G29.9-0.0 and G45.1+0.1 studied in Paper I. G25.4-0.2, at 5.5 kpc, is the closest HII region to the galactic center studied in this series. The region M8 has been extensively studied at optical wavelengths, allowing direct comparison of infrared and optical abundance estimates. DR22 is near S106 studied in Paper II, and S159 is another example of a Perseus arm HII region (S158 and S156 were studied in Papers I and II respectively). Since Talent and Dufour (1979) have suggested substantial abundance gradients along the Perseus arm, these latter HII regions are of particular interest.

The fine structure lines studied here include the [ArIII] and

[ArII] lines at 8.99μm and 6.99μm; the [SIII] and [SIV] lines at 18.71μm and 10.51μm; and the [NeII] line at 12.81μm. These argon and sulphur ionization states constitute the major ionization states for HII regions with exciting stars of temperature $T_* = 30{,}000$-$45{,}000K$ for sulphur and $T_* = 25{,}000$-$40{,}000K$ for argon according to simple dust-free ionization structure models (e.g. Lacasse et al. 1980; Lacy 1980). The ionic fraction of NeII is expected to be strongly correlated with the ratio of SIII/SIV (see Herter, Helfer and Pipher, 1983), so that total atomic abundances of argon, sulphur, and, neon can be obtained from these observations.

In section II we present the observational techniques employed, and a brief review of the methods outlined in Papers I and II for estimating and applying extinction corrections and determining ionic and elemental abundances. Individual source data and subsequent abundance estimates are given in section III, and a summary of the abundances from the present work and Papers I and II is presented in section IV.

II. Observations

The data described here were obtained with a variety of infrared systems. Ground-based data were obtained primarily at the Kitt Peak National Observatory (KPNO), Cerro Tololo International Observatory (CTIO) or at the UCSD - U. of Minnesota Mt. Lemmon Observatory using CVF spectrometers with resolutions $\Delta\lambda / \lambda \sim 0.015$. These data, both previously published and new results, are noted in

Table 1. Sampling densities are typically one to two data points per resolution element. Chopper spacings employed for each object are given in §III.C.

The 4-8μm data reported here consist of observations in the [ArII] line and adjacent continuum using the UCSD filter wheel spectrometer with a resolution of $\lambda/\Delta\lambda$ of 0.015 (Russell, Soifer, and Willner 1977; Puetter et al. 1979) on flights of the Kuiper Airborne Observatory (KPO) in July 1980, June and August 1981. For these observations a 27" focal plane aperture was employed, and chopped beam spacing and orientation were chosen to avoid beam cancellation.

The [SIII] 18.71μm line fluxes of G25.4-0.2, S159, and G45.5+0.06 were obtained with a 10-channel cooled-grating spectrometer (McCarthy, Forrest, and Houck, 1979) in July 1980. A focal plane aperture of 30" was used and the spectral resolution was approximately 0.2 μm. Observations of the [SIII] lines of M8 and DR22 were made with a 3-channel cooled-grating spectrometer (Herter et al. 1982b) in August 1981. The focal plane aperture was approximately 20" and the spectral resolution was 0.033μm. For both sets of observations the choice of beam throw was similar to that used with the UCSD instrument.

The observed line fluxes (uncorrected for extinction) are listed in Table 1 along with the beam sizes and references for previously published observations. The line fluxes for all but [ArII] have been derived from a least squares fit to the observations of the form $F_\lambda = a+b\lambda + c\{\exp - [(\lambda-\lambda_c)/\sigma_\lambda]^2\}$, that is

a linear continuum plus unresolved line emission at $\lambda = \lambda_c$, and $\sigma_\lambda \sim 0.6\,\Delta\lambda_{FWHM}$ where $\Delta\lambda_{FWHM}$ was determined from laboratory measurements. We vary a, b, c to minimize $\chi^2 = \Sigma\ \left(\frac{F_{obs} - F_{model}}{obs\ error}\right)^2$. For [ArII] only one point in the line and one on either side in the adjacent continuum were used to estimate the line flux.

III. Discussion

A) Estimating Extinction

In Paper I we extensively discussed the nature of the extinction correction, and here we will only briefly review the correction techniques and the uncertainties involved. The extinction can be computed from the brightness of the hydrogen emission lines or from the depth of the 9.7μm silicate absorption. In the former method, we can accurately compute the extinction at 2.17μm and 4.05μm by comparing observed and predicted Brackett line fluxes with the free-free radio flux density or by comparing the observed and predicted ratio of the Brackett line fluxes and assuming the form of the extinction law from 2 to 4μm. However the short wavelength extinction cannot be easily extrapolated to the longer wavelengths at which the fine structure lines appear. Alternatively, the 9.7μm silicate extinction (Gillett et al. 1975) can be determined by fitting the absorption spectrum of the 8-13μm continuum radiation with an opacity law τ_λ which fits the optically thin emission from hot dust in the Trapezium. For some sources, unidentified emission features at 7.7, 8.6, and 11.3μm strongly affect the

spectrum. For these sources, a multi-component fit of the form developed by Aitken et al. (1979) and Jones et al. (1980) is used to provide a better estimate of $\tau_{9.7}$.

For each source, all of the available techniques have been used to estimate the extinction. A single extinction law, given in Paper I, was used although there is no guarantee that the extinction law is the same from region to region. The extinctions derived from the different techniques were converted to values of $\tau_{9.7}$ and the mean was computed for each source. The means $\bar{\tau}_{9.7}$ are listed in Table 1, along with their uncertainties. The stated uncertainties in the corrected line fluxes and calculated abundances include the estimated uncertainty in the adopted $\bar{\tau}_{9.7}$.

B) Estimating Abundances

Ionic abundances were estimated by comparison of the corrected line fluxes with radio flux densities, measured at wavelengths short enough that the nebulae are optically thin (Equation 3, Paper I). The electron temperature was assumed to be 7500K and the ratio of electrons to protons 1.15. The electron density was estimated from the radio flux density and source size with an assumed filling factor of 1. New, more reliable and accurate values of the sulphur collision strengths have been employed (Mendoza, 1983) in computation of the ionic abundances, listed in Table 2. Table 3 lists the revised SIII and SIV abundances (using the new collision strengths) for objects studied in Papers I and II.

The prescription for computing total atomic abundances for argon and sulphur from the ArII, ArIII, SIII, and SIV observations was discussed in Paper I. The abundances thus computed, and displayed in Figure 1, are strictly lower limits to the total abundance because

1) other ionization states may be present,

2) clumping may cause us to underestimate ionic abundances, and

3) sources extended with respect to measurement beam sizes lead to exclusion of certain ionic contributions, as discussed in Paper I.

Since only one ionization state of neon was observed (NeII) it is more difficult to calculate the total neon abundance. However, in spherical, uniform models of HII regions employing the OTS approximation with charge exchange included, under the assumption of uniform temperature, it is found that the ionic fraction of NeII/Ne is correlated with the ratio of SIII/SIV, so that the total neon abundance can also be estimated from the NeII measurement (Herter, Helfer, and Pipher 1983).

The mean electron density, distance, and galacto-centric radius for each region are given in Table 4.

C) Individual Sources

G25.4-0.2 = W42

Radio maps of the G25.4-0.2 region show two sources; the one we studied[3]

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[3] $\alpha_{1950} = 18^h35^m26.^s5$, $\delta_{1950} = -06°48'38''$

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has a half power diameter of 10" and total diameter 20". The kinematic distance is 4.7±0.7 kpc (Reifenstein et al. 1970). It is situated near overabundant HII regions G29.9-0.0 and G30.8-0.0 (Paper I and Lester et al. 1981), which are also within 6 kpc of the galactic center. Felli, Tofani, and D'Addario (1974) give a 10.7 GHz radio flux density for this component of 2.5 Jy; Herter and Krassner (1984) observed the source on the VLA at 5 GHz and confirm the flux density of Felli et al.. The diameters and position of Herter and Krassner are listed above. Observations of the 8-13μm spectrum of G25.4-0.2 were obtained on the KPNO 2.1-m telescope in June 1980 with a beam throw of 25" and 14."8 aperture which included 80% of the radio flux. A model II fit to the very deep silicate feature in the 8-13μm spectrum gives $\tau_{9.7}$ = 5.3±0.3, and the only fine structure line observed was the [NeII] line. Observations of the [SIII] and [ArII] lines were obtained in July 1980 and June 1981 on the KAO, with a 2' beam throw. Abundances were computed assuming S_ν = 2.5 Jy for the [ArII] and [SIII] lines, and S_ν = 2.0 Jy for the [NeII] line.

G45.5+0.06

G45.5+0.06 has been extensively studied in the radio and infrared. Zeilik, Kleinmann, and Wright (1975) mapped this compact HII region at 10.6μm and also presented photometry; in addition, Zeilik and Heckert (1977) mapped the region at 2.2μm with a large

beam (1'). Radio maps by Matthews et al. (1977) at 5 GHz with a resolution of 7" x 35" reveal that G45.5+0.06 consists of three components, a 13" diameter source A of 3.3 Jy radio flux density, and two more diffuse low density components B and C of 26" and 100" respectively. At an adopted kinematic distance of 9.7 kpc (Reifenstein et al.), Matthews et al. conclude that a 47,000K ZAMS exciting star is necessary to ionize component A.

The 8-13μm spectrum, obtained with a 14".8 aperture and a 28" beam throw at the KPNO 2.1-m telescope in June 1980, was taken by offsetting to radio position A of Matthews et al. and peaking up on the [NeII] flux. All three fine structure lines available in this wavelength range are present. There is some indication that the unidentified 11.3μm emission feature may be present. The substantial silicate extinction is reproduced by a model II fit with $\tau_{9.7}$ = 3.1, or a multi-component fit of 2.6 if graphite grains are present, and 3.0 if they are not. We adopt $\tau_{9.7}$ = 2.8±0.4, since we do not have 2-4μm data on this source.

The [SIII] and [ArII] line flux measurements were obtained on the KAO in June 1980 and July 1981 respectively, with beam throws of 2'.

Ionic abundances were computed from the corrected line fluxes assuming that component A is the major contribution to the ionized gas. Any contribution from other more diffuse components should have been cancelled out by chopping.

M8

M8 and the surrounding region is one of the most extensively studied HII region/molecular cloud complexes. In the vicinity there is a young cluster (NGC 6530), the 'Hourglass' bright optical HII region, and more extended diffuse optical emission. While 9 Sgr is thought to power much of the optical nebulosity, the O7 star Herschel 36 may power the nearby Hourglass (Thackeray 1950, Woolf 1961). Maps at radio wavelengths show that the radio center coincides with the northern lobe of the Hourglass (Turner _et al_. 1974, Wink _et al_. 1975): a high resolution VLA map at 5 GHz (Woodward _et al_. 1984) is used in the analysis below. Infrared maps by Dyck (1977), Wright _et al_., Zeilik (1979), Thronson, Loewenstein, and Stokes (1979) and Woodward _et al_. show peaks at or near the northern Hourglass/Herschel 36 region. An 8-13μm spectrum centered on the narrow 'waist' of the Hourglass was obtained on the KPNO 2.1 m telescope in a 15" aperture with a 60" beam throw in June 1980, and a partial 2-4μm spectrum was obtained on the CTIO 1.5-m telescope in July 1980 in a 9" aperture, with a 30" beam throw. Observations of the [ArII] and [SIII] lines were obtained at KAO in June and August 1981. The extinction to M8 has been estimated by a multicomponent fit to the 8-13μm spectrum as $\tau_{9.7} = 0$. This is in excellent agreement with the visual estimate to the Hourglass of $A_v = 2.4$ assuming Orion-type selective extinction or $A_v = 1.1$ assuming standard selective extinction [Johnson 1967]. Lynds and O'Neil (1982) find $A_v = 3.6$ assuming a standard extinction law. We cannot reliably estimate the extinction from the Brγ flux and VLA radio map

since there is evidence of a possible compact source with partially optically thick Brackett lines in the beam. Hence the corrected line fluxes are taken to be equal to the observed line fluxes. Ionic abundances are computed using the 5 GHz VLA radio flux density estimated for the appropriate beam size (Woodward _et al._).

S159A = AFGL3053

S159A was included in the 5 GHz aperture synthesis observations of Perseus arm HII region by Israel (1977). The radio diameter of the compact component is 6" and the optically-thin 5 GHz density is 1.0 Jy. Rossano and Russell (1981) found an extended component as well; in a 4'5 beam at 3.2 GHz, the radio flux density is 2.43 Jy. An exciting star of $\sim$ 35,000K is required to support the radio emission, hence S159A is a fairly low-excitation compact HII region. S159 is near a peak in the CO emission and is at the position of an optically bright wisp as noted by Israel. The 8-13μm spectrum of AFGL3053 was obtained by Merrill (1977) with a 17" beam and a 50" beam throw at Mt. Lemmon in 1976 December; that spectrum shows a substantial [NeII] line as well as very strong 8.6 and 11.3μm unidentified emission features. The [ArII] and [SIII] measurements were obtained on KAO in 1981 June and 1980 July respectively.

Because 8.6μm and 11.3μm features dominate the 8-13μm spectrum, it is necessary to use a multi-component fit to estimate the extinction. We conclude on the basis of the fit that $\tau_{9.7} = 0$, and list the corrected line fluxes equal to the measured line fluxes in Table 1.

Ionic abundances are computed assuming $S_\nu = 1.0$ Jy.

DR 22

DR 22 is one of the 27 sources found in a 5 GHz survey of the Cygnus X complex by Downes and Rinehart (1966). Felli et al. (1974) found DR 22 to be $\sim 16''$ in size with a 10.7 GHz radio flux density of 3.2 Jy. High resolution radio maps of DR 22 at 2.7 GHz (Krassner et al. 1983) and on the VLA at 5 GHz (Herter and Krassner 1984) yield a size of 22", and the radio flux density can be supported by an exciting star of $\sim$ 37,000K. The 2-4 and 8-13μm spectra of DR 22 were obtained with an 11" aperture with a 53" NS beam throw at the radio peak by Herter (1984), and the [ArII] and [SIII] were data obtained in June and August of 1981. Herter (1984) mapped DR 22 in the Brackett lines and adjacent continua with an 11" beam, and found the extinction in the nebula varied from $\tau_{Br\gamma} = 1.4$ to 2.7. He deduced that abundance of [NeII] is remarkably constant with position in the nebula. The radio flux density used in the abundance analyses of [NeII], [ArIII], and [SIV] is 1.1 Jy derived from the extinction corrected Brγ and Brα fluxes.

IV. Abundances

We give the ionic abundances computed for each source in Table 2. G25.4-0.2 at 5.5 kpc from the galactic center is overabundant in ArII, SIII, and NeII. Since the half power size of G25.4-0.2 is

smaller than our measurement beam sizes, we can simply add ionic abundances of argon and sulphur to obtain atomic abundances. Because [ArIII] and [SIV] were not detected, we take the ArII and SIII abundances to be equal to the atomic abundances. Since SIII/SIV > 9, we estimate that NeII constitutes $\sim 90\%$ of the neon in the nebula (Herter, Helfer, and Pipher 1983). Thus neon is 2.4-2.7 times standard. Hence G25.4-0.2, like G29.9-0.0, is overabundant compared to standard abundances by approximately a factor of two.

Similarly, G45.5+0.06, at 7 kpc, is also small compared with our measurement beam sizes. We find total abundances of argon and sulfer to be 1.1 and 0.86 times standard abundances respectively. Since the ratio of SIII/SIV is 13 indicating a <u>much</u> softer UV radiation field than that of the single 47,000K star required to support the observed radio flux density, we conclude that most of the neon is NeII, and that the neon abundance is only 0.4 times standard abundance.

S159, a member of the Perseus arm, is 12 kpc from the galactic center, and is also small compared with our measurement beam sizes. It is a low excitation HII region, and most of the argon, sulphur and neon is in the ArII, SIII, and NeII ionic states. Hence atomic abundances of 1, 0.5 and 0.8 are deduced for argon, sulphur and neon respectively, i.e. we find S159 to have approximately standard abundances of these elements.

Both M8 and DR22 are extended with respect to our measurement beams, and are 9 to 10 kpc from the galactic center respectively.

Both M8 and DR22 have been studied in the radio at high resolution by Woodward et al. (1983) and Herter (1984), and these maps are used to compute total Ar and S abundances using the techniques discussed in Paper I. Maps in the [NeII] lines and studies of the extinction have been made for DR22 (Herter). We estimate the atomic abundances of Ne and S in DR22 to be consistent with standard abundances, while DR22 is slightly overabundant in Ar. M8 is apparently overabundant in Ne and Ar.

In figures 1a-d we have plotted the estimated atomic abundances of Ar, S and Ne as well as Ne^+, as compared with solar abundance for the sixteen HII regions we have studied in Papers I, II and the present paper, assuming no uncertainty in R, the galactocentric distance. In these figures, the Ne^+ abundances from Paper I have been adjusted to reflect the standard neon abundance used in Paper II, and these abundances have been converted to total neon abundances using the observed [SIII/SIV] ratios. Despite the fact there is scatter about the solar abundance value of $\sim \pm 1$ unit peak to peak, we immediately can conclude there is no compelling observational evidence for extreme abundance gradients in our Galaxy in these three elements. While there is a slight trend towards decreasing abundance with increasing galacto-centric radius R, the result depends heavily on the few observations obtained to date at $R \lesssim 6$ kpc. The formal results for argon, neon and sulphur are d log (Ar/H)/dR= -0.06/kpc, $\frac{d \log (Ne/H)}{dR} = -0.19$/kpc and $\frac{d \log (S/H)}{dR} = -0.10$/kpc respectively. These should be compared with O/H and N/H results

from 8-14 kpc in the solar neighborhood by Peimbert, Torres-Peimbert, and Rayo (1978) who quote gradients in the same units of -0.13 and -0.23 respectively. A recent paper by Shaver et al. (1983), using combined optical and radio observations, deduce oxygen and nitrogen gradients of -0.07, and -0.09 in the same units with very small scatter. Their results for other elements are less certain because of observational difficulties, but they suggest sulphur may have a much smaller gradient. The scatter in the present results is larger than they found for O and N. Talent and Dufour (1979) have derived substantial abundance gradients with galacto-centric distance along a given spiral arm using optical measurements: these determinations exhibit much less scatter than the global studies (both optical and infrared). We have not yet obtained a sufficient infrared sample along a spiral arm to assess these findings.

We must draw attention to W33, the low point at 6 kpc on all four figures. The argon and sulphur measurements lead to the conclusion that W33 is underabundant compared to standard. However, a previous large beam measurement in SIII showed it to be overabundant (McCarthy, 1980: see Paper I). A second small beam (20") measurement in SIII with chopper throws of 5' and 6' oriented NE to SW yielded results identical to those of Paper I (Herter, private communication). A possible explanation of the small beam SIII measurements is that high density clumps exist in the region: if so the SIII abundance is underestimated. Future plans include

measurement of the [SIII] 33μm line to estimate the density. Aperture synthesis maps of W33 recently published (Ho and Haschick 1981) may help future detailed studies of the region.

V. Conclusion

Abundances measurements for a total of 16 HII regions based on Ar, Ne and S infrared fine structure lines show a slight trend towards decreasing abundances with increasing galacto-centric radius. Region to region scatter at nearly constant radius is, however, as large as the alleged gradient. In particular, we measure low abundances for W33 at small radius, while S158 and S106 have high abundances at larger radii. The latter determinations seem secure, while the determination for W33 is less so.

The major uncertainties in abundance measurements in the infrared include 1) beam size corrections 2) extinction corrections and 3) corrections for unmeasured ionization states. The first two of these might potentially explain the low abundances derived for W33. As noted in §IV, the presence of high density clumps can dramatically affect the SIII emissivity, so that the S abundance would be underestimated (see Herter et al. 1982b). It is imperative that both ionization states of argon and sulphur be measured with the same large (with respect to source diameter) beam size if uncertainties due to item 1) are to be ruled out: an alternative method would be complete maps in the lines. Also, if a greater

number of hydrogen recominbation lines were measured in each region in order to tie down the extinction law, and hence the appropriate extinction for each fine structure line, with the same large beam, the second uncertainty could be alleviated. Finally, empirical relationships concerning the excitation conditions or correcting for the unmeasured ionization states are required. The total neon abundance has been estimated here from a model correlation between the NeII fraction and the [SIII/SIV] ratio, for example.

In spite of the uncertainties, there appear to be real differences between the abundances for different elements. There also appears to be a real spread in element abundances, at least at a galactocentric radius near that of the Sun.

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Table 1

Observed and Extinction Corrected Line Fluxes

Object	$\bar{\tau}_{9.7}$	Line	Beam (")	Flux[b] (10^{-18} Wcm^{-2})	τ_λ	Corrected Flux (10^{-18} Wcm^{-2})
G25.4-0.2	5.3±0.3	ArII	27	4.0±0.5	1.6±0.1	20±4
		ArIII	15	<0.4	4.2±0.2	<27
		SIII	30	5.0±1.4	3.2±0.2	123±42
		SIV	15	<0.5	4.5±0.3	<45
		NeII	15	20±2	1.9±0.1	130±20
G45.5+0.06	2.8±0.4	ArII	27	4±2	0.8±0.1	8.7±4
		ArIII	15	1.8±0.3	2.2±0.3	16±6
		SIII	30	16±1.5	1.7±0.2	88±19
		SIV	15	2.6±0.4	2.4±0.3	29±10
		NeII	15	12±1	1.0±0.1	33±4
M8	0.0	ArII	27	10±2.5		
		ArIII	15	2.3±0.3		
		SIII	20	26±1		
		SIV	15	<1.2		
		NeII	15	23±2		
		Brγ	9	0.23±.01		
S159	0.0	ArII	27	4.2±0.8		
		ArIII	22	<1.4		
		SIII	30	12±1.3		
		SIV	22	<1.7		
		NeII	22	20±1		
DR22	2.2±0.3	ArII	27	10.7±3	0.7±0.1	21.5±7
		ArIII	11	0.8±0.2[a]	1.8±0.2	4.8±1.6
		SIII	20	17±1	1.3±0.2	62±13
		SIV	11	<1.2[a]	1.9±0.3	<8
		NeII	11	7.1±1.0[a]	0.8±0.1	16±3
		Brγ	11	0.12±.01[a]	2.25±0.3	1.14±0.15
		Brα	11	0.97±.04[a]	1.20±0.15	3.22±0.4

Notes

a. Measurements at peak radio flux position.
b. Uncorrected for extinction.

Table 2
Determination of Ionic Abundances

Object	Line	S_ν (Jy)	$j/n_x{}^i n_e$ (10^{-22} erg cm^{3}s^{-1}sr^{-1})	$n_x{}^i/n_H$ (10^{-6})	$(n_x{}^i/n_H)$ (with respect to standard atomic abundance)*
G25.4-0.2	ArII	2.5	3.14	9.0±1.8	1.9±0.4
	ArIII	2.0	7.24	<6.6	<1.4
	SIII	2.5	5.82	30±10	1.8±0.6
	SIV	2.0	25.94	<3.06	<0.2
	NeII	2.0	0.940	243±30	2.4±0.2
G45.5+0.06	ArII	3.3	3.16	2.9±1.5	0.6±0.3
	ArIII	3.3	7.46	2.3±0.9	0.5±0.2
	SIII	3.3	7.67	12±2	0.8±0.2
	SIV	3.3	30.19	1.0±0.4	0.06±0.02
	NeII	3.3	0.961	37±4	0.36±0.03
M8	ArII	1.91	3.16	6.4±1.6	1.4±0.4
	ArIII	0.67	7.46	1.8±0.2	0.38±0.05
	SIII	1.24	7.93	10.2±0.4	0.64±0.24
	SIV	0.67	31.16	<0.25	<0.02
	NeII	0.67	0.961	43±13	1.39±0.08
S159	ArII	1	3.14	4.7±0.9	1.0±0.2
	ArIII	1	7.24	<0.7	<0.2
	SIII	1	5.82	7.5±0.7	0.46±0.05
	SIV	1	25.94	<0.25	<0.01
	NeII	1	0.940	75±4	0.75±0.03
DR22	ArII	3.2[b]	3.17	7.0±2	1.5±0.4
	ArIII	1.1[a]	7.59	2.2±0.5	0.46±0.10
	SIII	3.2[b]	9.32	6.6±1.7	0.42±0.09
	SIV	1.1[b]	33.33	<0.9	<0.06
	NeII	1.1[b]	0.973	60±6	0.60±0.06

*Assumed Standard Abundances: S/H=1.6×10^{-5}; Ar/H=4.7×10^{-6}; Ne/H=1.0×10^{-4}

a. ν=10.7GHz

b. deduced from Brγ flux corrected for extinction.

Table 3

Revised* Sulfur Ionic Abundances $\frac{({}^{n}x^{i}/{}^{n}h)}{({}^{n}x/{}^{n}h)\ \text{standard}}$ For Objects From Papers I & II

PAPER	SOURCE	SIV	SIII	GALACTOCENTRIC RADIUS R(kpc)
I	G29.9-0.0	<0.06	1.0±0.39	5
	G12.8-0.2	0.04±0.01	0.22±0.05	6
	G45.1+0.1	0.08±0.03	0.37±0.08	7.5
	G75.84+0.4	0.06±0.006	1.21±0.06	10
	W3IRS1	0.14±0.04	0.67±0.12	12
	NGC7538IRS2	0.01±0.02	0.34±0.17	12.7
II	S88B	<0.07	0.48±0.34	9
	S156	----	1.00±0.18	11.7
	S106	<0.04	0.68±0.14	10
	NGC2170IRS1	<0.01	0.27±0.07	12.5
	M42(20"Nθ,C)	0.09±0.01	0.61±0.06	10.5

*Using the collision strengths of sulphur (Mendoza 1983).

Table 4

Assumed Physical Parameters of Observed Objects

Objects	n_e^{rms} (cm^{-3})	Distance d(kpc)	Galactocentric radius R(kpc)
G25.4-0.2	10^4	4.7±0.7(13.4±0.7) [near and far distances]	6.1
G45.5+0.06 Component A	5800	9.7	7.6
M8 (in a 9" beam)	5000	1.8	8.2
S159	10^4	4.5	11.7
DR22	3400	3.4±1.8	10

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Figure Captions

1 a. Ratio of $n_x/n_{standard}$ = $(Ne^+/H)/(Ne/H)_{standard}$ as a function of galactocentric radius R; $12+\log(Ne/H)_{standard}$ = 8.0.

b. Ratio of $n_x/n_{standard}$ = $(Ne/H)/(Ne/H)_{standard}$ as a function of galactocentric radius R; $12+\log(Ne/H)_{standard}$ = 8.0.

c. Ratio of $n_x/n_{standard}$ = $(Ar/H)/(Ar/H)_{standard}$ as a function of galactocentric radius R; $12+\log(Ar/H)_{standard}$ = 6.67.

d. Ratio of $n_x/n_{standard}$ = $(S/H)/(S/H)_{standard}$ as a function of galactocentric radius R; $12+\log(S/H)_{standard}$ = 7.20.

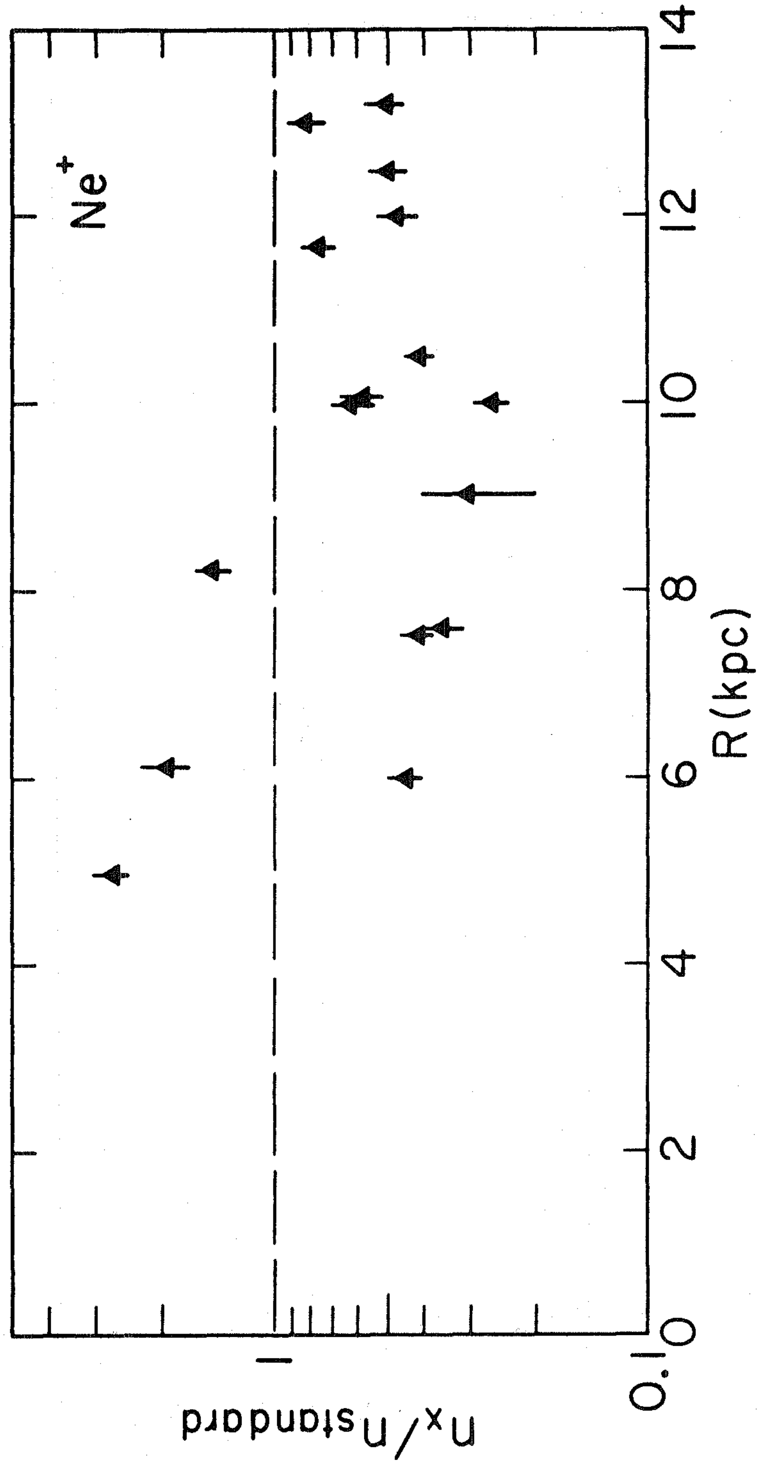

Fig. 1a

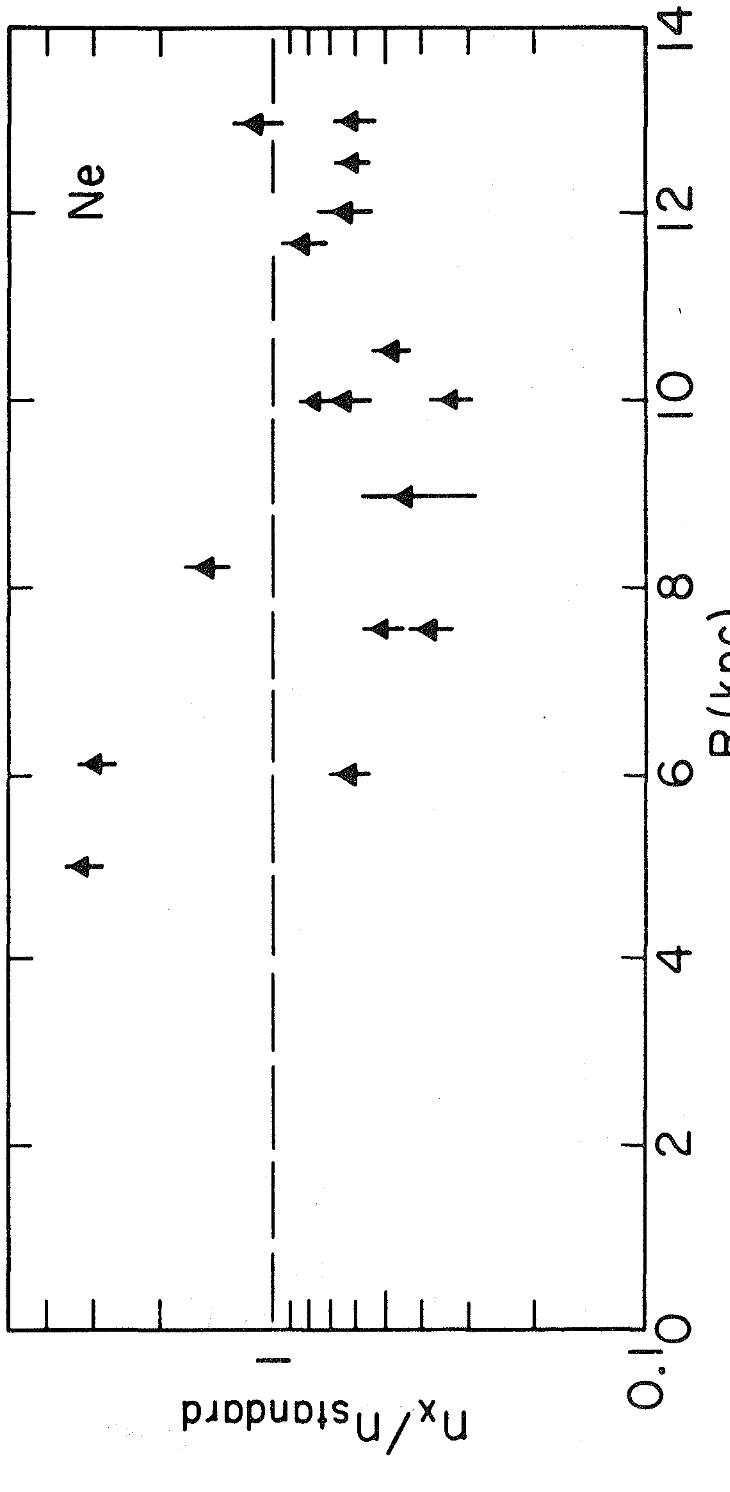

Fig. 1b

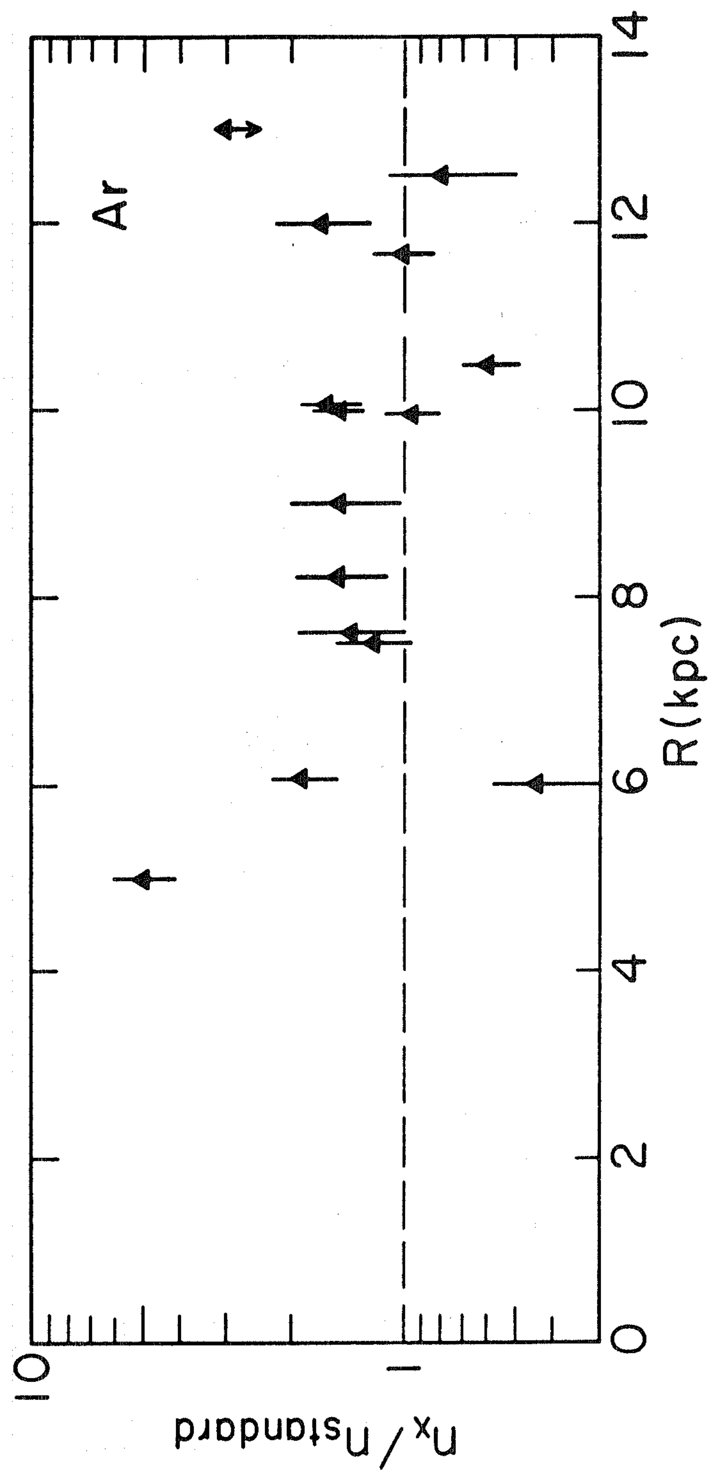

Fig. 1c

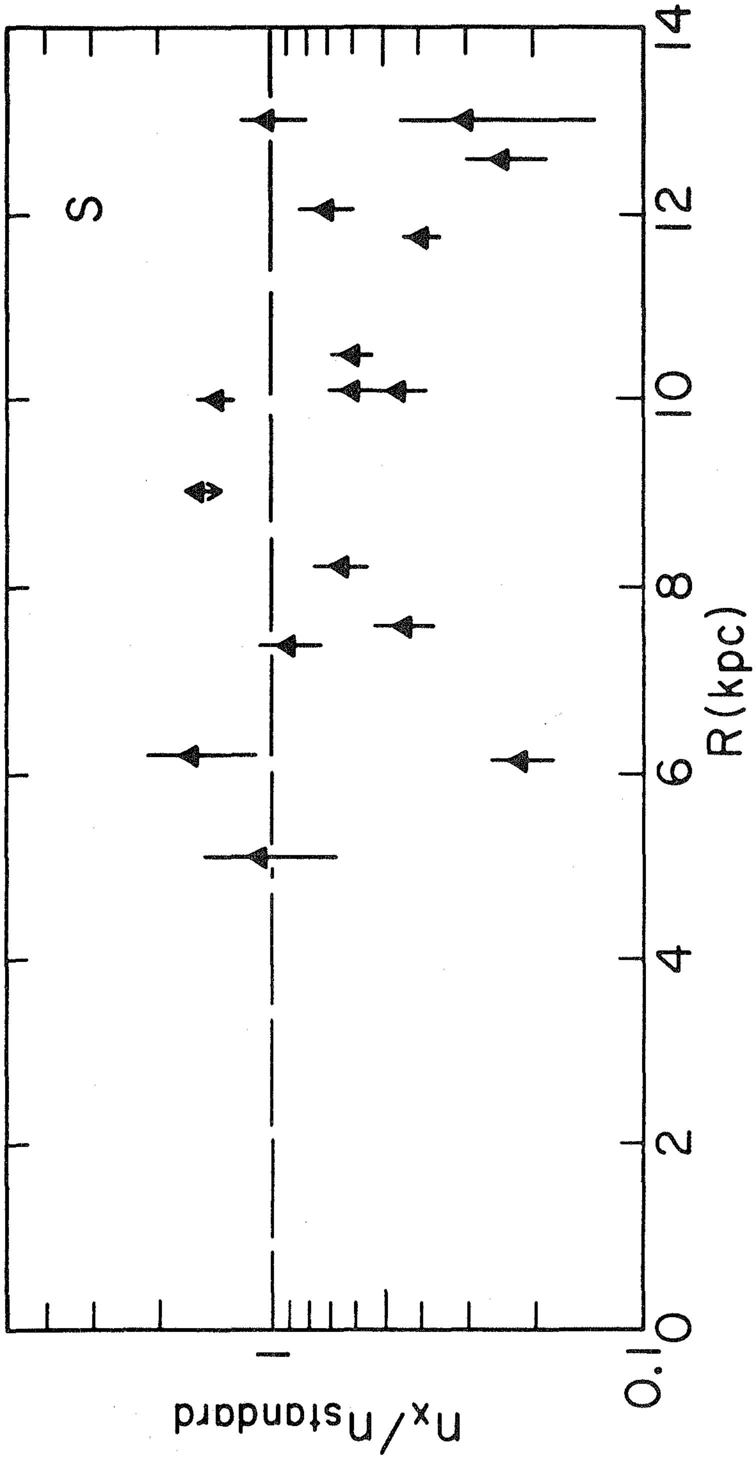

Fig. 1d

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16. Abstract

Measurements of the [ArII](6.99 μm), [ArIII](8.99 μm), [NeII](12.81 μm), [SIII](18.71 μm), and [SIV](10.51 μm) lines are presented for five compact HII regions along with continuum spectroscopy. From these data and radio data we deduce lower limits to the elemental abundances of Ar, S, and Ne. G25.4-0.2 is only 5.5 kpc from the galactic center, and is considerably overabundant in all these elements. G45.5+0.06 is at 7 kpc from the galactic center, and appears to be approximately consistent with solar abundance. S159 in the Perseus Arm, at 12 kpc from the galactic center, has solar abundance, while M8 in the solar neighborhood may be somewhat overabundant in Ar and Ne. DR22, at 10 kpc from the galactic center in the Cygnus Arm, is overabundant in Ar. A summary of results from our series of papers to date on abundances is given.

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